Application Nos. 1394112, 1409180 and 1481725

ALBERTA ENERGY AND UTILITIES BOARD

IN THE MATTER OF the *Alberta Energy and Utilities Board Act*, R.S.A. 2000, c. A-17, the *Energy Resources Conservation Act*, R.S.A. 2000, c. E-10, the *Oil and Gas Conservation Act*, R.S.A. 2000, c. O-6 and regulations thereunder, the *Oil Sands Conservation Act*, R.S.A. 2000, c. O-7, and section 3 of the *Oil Sands Conservation Regulation*, AR/76/88, all as amended;

IN THE MATTER OF Alberta Energy and Utilities Board ("EUB" or "Board") Interim Directive ID99-1, as amended ("ID99-1");

IN THE MATTER OF Application No. 1394112 by Canadian Natural Resources Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area;

IN THE MATTER OF Application No. 1409180 by EnCana Corporation to the Board for approval to produce gas in the Clearwater Formation in the Fisher field of the Cold Lake Oil Sands Area;

AND IN THE MATTER OF Application No. 1481725 by Husky Oil Operations Limited requesting the Board shut in gas production in the Clearwater Formation in the Cold Lake Oil Sands Area; and

AND IN THE MATTER OF EUB Notice of Rescheduling of Hearing dated October 13, 2007.

REPLY SUBMISSION OF HUSKY OIL OPERATIONS LIMITED

January 30, 2007

TABLE OF CONTENTS

1. Introduction and Executive Summary

It is common ground that Husky Oil Operations Limited ("Husky") holds 56 sections of bitumen leases (the " Caribou Area") contiguous to EnCana Corporation's ("EnCana") leases with gas production from the Clearwater Formation. Bitumen and gas in the Caribou Area are both reservoired in the Clearwater and Extensive gas production has occurred and is continuing. Furthermore, EnCana has applied to the Board for authorization to produce additional gas from the Clearwater. Husky has applied to the Board for an order requiring EnCana to shut in certain gas wells on the basis that EnCana's continued production from these wells will adversely impact Husky's recovery of bitumen resources it intends to produce using an experimental Hybrid Steam Assisted Gravity Drainage ("HSAGD") process.

In its filed submissions in this proceeding, EnCana has claimed that its continued and proposed production of gas will not adversely affect the economic development of Husky's bitumen resource. EnCana attempts to support this claim by postulating that there is a continuous and correlatable barrier between the gas and bitumen zones for which there is no evidence. EnCana has failed to provide supporting geological evidence for its assertion of a shale barrier. EnCana has neglected to model the HSAGD process that Husky is proposing to use. Further, EnCana's simulation is inappropriate for thermal processes such as HSAGD, and the underlying history match is unacceptable.

Husky has demonstrated that production of the adjacent gas caps will be detrimental to the recovery of Husky's bitumen resource. Husky's detailed geological study of the area, contrary to EnCana's unsupported claim, shows there are no laterally continuous and correlatable barriers between the gas and bitumen. Husky has provided a realistic simulation model that matches the history. Furthermore, Husky has modelled the HSAGD process that it intends to use at Caribou.

The pressures in the gas caps have been depleted significantly from the initial pressures and continue to be depleted. Extensive piezometer data in Husky's Caribou leases located in the bitumen zone show pressure drops in excess of 50% in places and the pressure depletion is ongoing. The pressure depletion in the gas cap is communicated vertically and laterally into the bitumen zone through the top water where present or the initially mobile water phase in the bitumen zone where top water is absent.

Husky has a significant resource over the entire lease: 1.1 billions barrels of this resource reside in Husky's 15 section lease (Lease Number 7188110343) area. Continued depletion of pressure resulting from EnCana's continued production from its adjacent wells will significantly harm the ultimate bitumen recovery by either HSAGD or Cyclic Steam Simulation ("CSS") processes. These observations are fully consistent with Husky's simulations of the HSAGD and CSS processes and also established experience and learnings of the CSS process. Significant amounts of solution gas are evolving from the bitumen due to pressure depletion. This gas is migrating to the gas pools. In addition to confirming that no pressure barriers exist, this loss of solution gas will have a significant detrimental effect on bitumen recovery.

Shutting in the gas production is required to stop the continued pressure depletion and the resulting loss of solution gas. Specifically, in this Reply Submission, Husky addresses the following EnCana claims:

1.1 EnCana's claim that pressure depletion in the gas pools does not adversely affect the bitumen recovery is unsupported.

Husky has presented pressure data confirming pressure depletion. Husky's piezometer readings are consistent and provide ample continuous pressure data over time. The evidence is clear and overwhelming that pressure depletion resulting from EnCana's gas production is communicated to Husky's leases. Husky has been able to demonstrate, through detailed geological studies and rigorous reservoir simulation that there is a significant risk to the bitumen resource as a result of continued gas cap production.

1.2 EnCana's conclusion that continued gas production will result in "no harm to bitumen" is based on modelling that is fundamentally flawed for the following key reasons:

(a) **The geological foundation for EnCana's numerical reservoir model is incorrect: EnCana has failed to incorporate a realistic geological model of the Caribou Area into its numerical reservoir simulation model.**

EnCana provides no discussion of the depositional setting. The absence of a basic understanding of the distribution of facies, severely limits the ability to predict the distribution of reservoir properties.

In its reservoir model, EnCana introduced a phantom vertical transmissibility barrier between the gas and water, extending over almost the entire gas cap area. There is absolutely no geological justification for such a barrier.

EnCana has not presented a comprehensive geological distribution of shales. Husky has provided detailed distributions of shales. EnCana has failed to differentiate shales between the clay-rich barriers and baffles.

EnCana provides no discussion of the hydrocarbon emplacement, despite the fact that it uses hydrocarbon emplacement as a justification for the phantom transmissibility barrier, previously discussed.

Rather than acknowledging that significant volumes of gas are exsolving from the bitumen into the gas cap, thus providing pressure support and replenishing gas volumes, EnCana arbitrarily increased the size of the gas caps.

(b) **EnCana has failed to simulate the HSAGD recovery process that Husky intends to employ at Caribou**

EnCana made no attempt to model the HSAGD process that Husky intends to use.

HSAGD is a hybrid of SAGD and HWCSS. HSAGD must be modelled and analyzed as a separate and distinct hybrid process. Through its simulation of the HSAGD process, Husky has established that there is significant harm to the recovery of bitumen caused by loss of solution gas in the bitumen zone resulting from the lowering the reservoir pressure due to gas pool depletion.

(c) EnCana fails to assess the effects of producing gas to abandonment pressures (~200 kPa) prior to thermal recovery.

Gas production has been significant and is ongoing. Current gas pressures are approximately 1000 kPa, in stark contrast to the initial pressures of ~2800 kPa. EnCana's simulations use current gas cap pressures, not the long-term abandonment pressures. The result is to significantly understate the impact of the continued production of the EnCana gas on ultimate bitumen recovery.

EnCana fails to account for the fact that gas depletion to abandonment pressure will occur prior to any thermal recovery by Husky.

Gas can be produced after the bitumen recovery with no adverse effects. In contrast, bitumen cannot be produced after gas depletion without an adverse effect because of gas exsolution concomitant with production of the gas caps. This has significant implications for resource conservation as the industry considers the development of bitumen resources, whose recovery economics are dependent upon the use of newer reservoir pressure-sensitive technologies.

(d) EnCana uses an unrealistically low net to gross ratio of 10% in simulation layers under the gas cap

By using a low net to gross ratio of 10% under the gas cap, EnCana has not only reduced the volume of bitumen in this layer, but has also reduced the horizontal cross-sectional area open to flow, and thus the horizontal flow conductivity by 90%. There is no geological reason for this. The result is to artificially and improperly to reduce the effect of gas pressure decline on pressures within the bitumen, thereby reducing the effect that continued gas production has on the bitumen reserves.

(e) EnCana uses grossly oversized grid blocks for thermal recovery processes

In attempting to model both the gas production and the bitumen production in one global reservoir model, EnCana utilizes an extremely coarse grid for the reservoir volume affected by the thermal recovery processes. These grid block dimensions are far too large to allow the numerical model to capture the steam chamber growth and gravity drainage effects.

(f) EnCana uses inappropriate well spacing for its reservoir simulation

EnCana's horizontal spacing of its horizontal wells is far too large. Placing the wells 280 m apart prevents or severely inhibits the steam chambers from interacting and eventually coalescing, as would occur with SAGD, CSS, and HSAGD.

(g) EnCana's "horizontal" wells are slanted from heel to toe

EnCana's well trajectories are not truly horizontal. This has the effect of drowning the production wells, and possibly the toes of the injection wells, thereby impairing the production capacity of the process.

(h) EnCana's wells have erratic partial completions

EnCana's wells are not completed in all grid blocks penetrated.[1] As such, the wells cannot accept flow from all grid blocks and therefore do not realistically model the processes.

(i) EnCana's permeability data is not representative of the Clearwater Formation

EnCana's permeability plots do not include correct permeability data and underestimate the average maximum permeability. As such, the EnCana's simulations are incorrect.

(j) EnCana does not include reservoir heterogeneity

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir, i.e. "layer cake". The heterogeneity of the reservoir is a key factor affecting process performance and dynamics that must be included in models.

(k) EnCana uses an unrealistically low live oil viscosity of 17,000 cP

EnCana's live oil viscosity of 17,000 cp is far too low and not realistic for the Clearwater reservoir as supported by published data.

(l) EnCana's reservoir simulation model utilizes incorrect relative permeabilities

EnCana's oil relative permeability curve is concave downward and is not representative of the Caribou area, as is supported by Husky's special core analysis.

(m) EnCana did not use temperature-dependent relative permeability curves

EnCana failed to incorporate any temperature dependency of their relative permeability curves in its thermal simulations. EnCana states that temperature dependency would make no difference to their conclusions. This statement is not substantiated, and in Husky's opinion, incorrect

(n) EnCana failed to use dilation during CSS

The CSS process in bituminous oil sands requires fracture injection pressures and dilation to fully model the relevant physics. EnCana failed to inject at a sufficiently high steam pressure to

[1] KADE Technologies Inc., *Gas-Over-Bitumen Reservoir Simulation Study*, January 8, 2007 ("January 8th KADE Simulation")

invoke dilation. Furthermore, without dilation there is no compaction drive during the production phase of each CSS cycle.

(o) EnCana's history match of pressures and production is flawed

The description of EnCana's history match procedure reveals that EnCana made numerous attempts to arbitrarily adjust the input data to obtain the history match of the pressures and production data. Despite these attempts, the history match plots given by EnCana demonstrate clearly that the history match of pressures and production is still of very poor quality:

- ***most piezometer pressures are not matched,***
- ***pressure trends were not matched, and***
- ***total water production is not matched.***

The failure of the history match raises serious questions in respect of the totality of EnCana's reservoir simulation model and consequently the results that are being used to justify EnCana's overall conclusion that continued gas production will have no effect on bitumen recovery.

EnCana acknowledges that pressure matches in the north were lower and to the south were higher and then asserts that "on average" the pressures were matched. Typically in history matching, the absolute deviations between simulation and field data are minimized and not averaged. Therefore, any prediction based on such a model is questionable and unreliable. Again, the failure of the history match makes the reservoir simulation model, its results, and any conclusions drawn from its results meaningless.

(p) EnCana's CSS results contradict the accepted principle that solution gas is an important drive mechanism in the CSS process

EnCana's model acknowledges significant solution gas evolution, but fails to acknowledge any effect on the CSS recovery processes. Solution gas is a known drive mechanism of heavy oil recovery using CSS. One cannot inhibit or eliminate this drive mechanism without an adverse effect on bitumen recovery.

(q) Husky's response to EnCana's additional simulations (EnCana IR to Husky January 24, 2007)

In duplicating EnCana's runs, Husky determined that the runs with the original operating strategy and new liquid constraint led to high gas production rates and water accumulation in the steam chambers which impaired oil production. Obviously, operating with a strategy where gas and potentially steam production is high and forming a zone largely saturated with water due to excessive steam injection is inefficient. Therefore, the operating conditions of the original model were not optimized and EnCana's results do not reflect the true deliverability of the reservoir.

Husky's current 2D simulations with a liquid constraint and a modified operating strategy using the same input parameters as before have more realistic production rates. Note that further optimization of the operating strategy is possible. With limited optimization, these last simulations confirm the harmful effects of gas cap depletion on bitumen recovery as shown by the original runs.

For all of the above reasons, Husky continues to submit that existing gas production must be halted and no new gas production should be permitted in the Caribou Area. Husky's detailed submissions are set forth in the following sections.

2. EnCana Fails to Properly Model the Geology of the Clearwater Formation and Gas and Water Zones

EnCana fails to properly model the geology of the Clearwater Formation, and the associated gas and water zones.

(a) EnCana does not provide a discussion of the depositional setting

EnCana has not provided a geological interpretation of the depositional setting of the Clearwater Formation in the Caribou Area. Failure to understand the lateral and vertical distribution of the facies essentially undermines any understanding of vertical or horizontal permeability barriers. An understanding of the depositional setting is the necessary first step to assessing the impacts of continued, and indeed increased, gas production on bitumen recovery.

(b) EnCana Models Phantom permeability barriers

EnCana's application of phantom permeability barriers in simulation work, accomplished with a transmissibility reduction, is indefensible. EnCana's simulation work encompassing an impermeable layer under the water zone[2] is neither supported by core nor wireline log data, and is contrary to a reasonable interpretation of the geology of the Caribou Area. The assertion, as reflected in EnCana's simulation models, that some form of barrier exists is contrary to any realistic and reliable geologic model.

EnCana introduces a vertical permeability barrier under the water zones by arguing that:

(i) The density difference between bitumen and water would have caused gravity segregation, had there been no barrier[3], and

(ii) bitumen failed to displace water thus there is barrier.

Husky dealt with this matter in its response to the Board's September 5, 2006 information request to Husky, Question 2:

(i) invading oil displaced the original mobile formation water,

(ii) oil degraded to bitumen, releasing methane as a byproduct,

(iii) this methane accumulated as a gas cap,

(iv) subsequent removal of overburden resulted in leakage of gas,

[2] EnCana's response to Husky January 12, 2007 information request 6.
[3] EnCana's response to Husky January 12, 2007 information requests.

(v) gas migration was followed by an influx of water to replace the voidage, and

(vi) water preferentially filled the base of the gas cap because bitumen was too viscous and too similar in density to be displaced.

EnCana has provided no reliable justification for its postulated permeability barrier. The existence of water over bitumen is not indicative of a barrier because the density difference between the two liquids is very small; combined with the high oil viscosity, the differential densities would result in too small of a driving force to overcome capillary pressures. Lastly, no impermeable physical barrier has been observed in the core data[4].

Husky has performed a comprehensive review of available geologic data for the Caribou Area. There is no geologic evidence of a laterally continuous and competent physical barrier to vertical flow under the water zone and therefore no barrier for pressure transmission from the gas cap to the underlying bitumen. There are no laterally continuous observable barriers, and none can be inferred. The presence of gas over water over bitumen is well understood as a result of the hydrocarbon emplacement model in Northern Alberta.

The suggestion that there is a barrier because of the existence of the water zone is expressly contrary to the many findings of the Board that the pressure communication will be transmitted through the gas and the water to the underlying bitumen, in the absence of laterally continuous and competent barriers.

(c) Shales are not Laterally Continuous in the Caribou Area

EnCana failed to present a comprehensive geological description of the depositional setting, and therefore presents no evidence as to the types and distribution of shales across the area of concern.

Husky provided an interpretation of the depositional setting for the Clearwater Formation in the Caribou Area.[5] Husky's core and log review has resulted in a detailed interpretation that consistently explains Husky's piezometer observations by establishing the lateral and vertical pathways for pressure communication

The Husky regional facies distribution **(Figure 2.1)** reflects an interpretation of the reservoir as an Incised Valley System opening towards the north-northwest. The valley system is two-sided such that it has incised into a regional highstand, deltaic, muddy shoreface that is preserved on both the east and west side of the incised valley complex **(Figure 2.2)**. Husky refers to the bordering muddy shoreface units as the "Western Regional Shale" and the "Eastern Regional Shale." These two shale units in core and well logs appear to be regionally correlative, clay-rich units that probably constitute permeability barriers **(Figure 2.3)**, but the shale on the east side is of limited extent. These possible impermeable barriers in the east are found outside Husky's Lease.

[4] Husky's response to EnCanas October 17, 2006 information requests.
[5] Husky's response to EUB November 10, 2006 information request, 1a.

Eroded into the regional shales is the incised valley fill, which constitutes the main target reservoir on the Husky Caribou lease. The incised valley fill can be broadly differentiated into a central sand-rich axis, flanked on the east and west by marginal valley deposits. The central sand-rich axis appears to merge into the marginal valley deposits without sharp lateral facies boundaries. Both facies are characterised by interbedded mud stringers, but the marginal valley deposits on the east flank of the complex are much more mud-rich with a strong brackish marine signature reflected in the trace fossil assemblages.

The mud-rich marginal valley is distinctly different from the adjacent Eastern Regional Shale, and does not constitute laterally continuous shale barriers. Rather, the marginal valley facies consists of interbedded, discontinuous mud stringers and mud clasts **(Figure 2.4)**, similar to that seen in the sandy axis facies, but in greater concentration. It is also observed that all of the interbedded sands are bitumen-saturated, indicating that they are interconnected and that they did not constitute a barrier during hydrocarbon migration and emplacement. This is indicative of potential pressure connectivity across these facies.

There are places where there is gas over water over bitumen with no mud in between, and there are places where there is gas over water over interbedded sandy mud layers. Therefore, EnCana's geological model as reflected in its simulation work, where there is an impermeable shale layer within the water zone, is not supported by, and is in fact contrary to, the core data.

In summary, Husky's bitumen leases lie directly in an incised valley, where older sediments have been cut and re-worked, resulting in no laterally continuous and competent barriers. There are two adjacent mud-rich facies on the eastern side of the system. The muddy interbedded valley margin shales combined with the immediately adjacent eastern regional shale constitute the two components of what Husky informally refers to as the "Eastern Shale Complex" and CNRL refers to as the "C&D muds".

Husky, in distinction to EnCana, has provided a reasonable and comprehensive interpretation of the shales, their properties, and their distribution. Any realistic simulation work must reflect the absence of any continuous and competent barriers between the overlying gas and the bitumen.

(d) EnCana has failed to differentiate shales

EnCana has failed to differentiate the two discrete shale units that make up the Eastern Shale Complex[6], and appears to have assigned permeability properties seen in the eastern regional shale to the entire complex without recognizing that the valley margin shale (western subunit, **Figure 2.1**) has a measurable and significant permeability (30 to 500 mD).[7]

Husky differentiates the shales in the East Regional Complex: an eastern subunit which is a solid mud (barrier shale) and a western subunit which is interbedded sandy mud with finite permeability (baffle shale) and would not act as barrier.

[6] EnCana's response to Husky information request 07.01.12; Drawing 5, Isopach of C to D Mudstone.
[7] Husky's response to EUB information request 07.01.12, 2a.

On the Husky Leases shales are not continuous and, in addition Husky simulation work honours lab-derived data in relation to the shales themselves. The valley margin shale component will act as a baffle shale and could not be a regional barrier. EnCana's submission demonstrates a lack of the geological input that is absolutely necessary for proper reservoir modeling and simulation work.

(e) EnCana does not provide an explanation for hydrocarbon emplacement

EnCana failed to provide an explanation for emplacement of the hydrocarbons in the Clearwater Formation reservoir. However, EnCana does allude to the bitumen displacing the water.[8] Husky disputes that this is possible. An understanding of hydrocarbon emplacement does not have to invoke the presence of significant lateral and vertical permeability barriers, again, refuting the application of such barriers in their simulation.

Husky supports the conventional hydrocarbon emplacement model (Aitken et al., 2004; Larter et al., 2003) which readily explains the presence of gas over water over bitumen. In such a model, no barriers are needed between the gas, water, and bitumen. This model is also consistent with the existence of multiple pressure communication pathways between the bitumen and the gas cap.

(f) EnCana's speculation that water over bitumen suggests barriers to flow is flawed.

EnCana's contention that the presence of water over bitumen suggests barriers to flow is unsubstantiated.9 Husky outlined the commonly accepted theory for development of the gas over water over bitumen situation in our response to the Board information request 06.09.05, 2. Mobile hydrocarbons migrate through porous and permeable sediments into a trap. Biodegradation of the oil phase occurs, creating bitumen and gas as by-products. Subsequent natural migration of the gas allows water to displace some of the gas resulting in gas over water over bitumen. All facets of this hydrocarbon emplacement require a porous and permeable reservoir, with no lateral or vertical permeability barriers. This, once again, is contrary to the application of artificial permeability barriers to facilitate history matching, as done by EnCana in their simulation work.

(g) EnCana's calculated OGIP is unjustified

Husky notes that EnCana's volumetrically calculated OGIP's are much smaller than its "history matched" final simulated volumes (D Pool increased by 30% and B Pool by 18%).10 No geological evidence has been presented for these larger volumes.

---

[8] EnCana Response to Husky information request 2007-01-12.
[9] EnCana's responses to Husky information request 07.01.12, 7a.
[10] January 8th KADE Simulation

Husky's detailed geological study and previous submissions11 disagree with EnCana's "history matched" volumes. Furthermore, the additional gas that had to be introduced to EnCana's numerical simulation model is most likely the solution gas that evolves from the bitumen as a result of pressure depletion and migrates into the gas pools. Clearly there are no barriers to solution gas migration into the gas pools. These pools must be shut in to prevent pressure depletion and resulting loss of solution gas in the bitumen zone.

3. The Caribou Area Contains a Valuable Bitumen Resource in the Clearwater Formation

Notwithstanding EnCana's unsupported assertions to the contrary, the fact is that the Caribou Area contains a valuable bitumen resource in the Clearwater Formation. Commercially viable thermal recovery operations exist in CNRL's Primrose field, in an extension to Husky's Clearwater reservoir, immediately to the south of Husky's lease.

Husky currently estimates that there are 1.1 billion barrels of bitumen in place in Husky's 15-section lease in the Clearwater Formation, all adversely affected by EnCana's gas production from the Clearwater Formation. The estimate of volume of bitumen in place may well increase with further delineation drilling.

Husky estimates ultimate bitumen recovery factors between 27% and 50% (300 to 550 million barrels). The remaining gas in the associated gas pools amounts to approximately 5 million boe. Consequently, the value of the bitumen resource vastly exceeds that of the remaining gas and the bitumen resource must be conserved.

EnCana provided an estimate of 2.7 billion barrels OBIP[12] for a 99-section area that encompasses Husky's 15 section lease. This significantly underestimates the total resource in jeopardy as a result of EnCana's exclusive use of core data, but nonetheless, EnCana's estimate indicates a significant resource worthy of protection.

Furthermore, the entire extent of the bitumen resource is yet to be fully evaluated. Limited drilling has occurred in the northern and western regions of Husky's two leases, and additional resource-bearing incised valleys could be identified by further delineation work.

Additional geological work and delineation drilling is underway. Husky is currently in a 44-well delineation drilling program. An additional 40 cores through the Clearwater bitumen reservoir will be cut, providing further valuable information to evaluate the extent and distribution of the resource. Consequently, the harmful effects of gas cap depletion to the bitumen resource are potentially applicable to much larger bitumen volumes than those that have already been identified.

The geologic evidence is clear that there is a valuable bitumen resource in the Clearwater Formation in the Caribou Area. Exploitation and recovery of this major bitumen resource is at

[11] P/Z plots as shown in Husky Response to Board Information Request, 06.11.10, Appendix A.
[12] January 8th KADE Simulation,

significant risk due to continued gas production and concurrent pressure depletion of the bitumen.

4. The Pressure Data Confirm that Pressure Depletion caused by Ongoing Gas Production by EnCana is Communicated Rapidly and Broadly

Husky has 31 piezometers installed in seven wells in the Caribou area. Twenty-five of 31 (81%) are recording monotonically declining pressures of up to 56% on November 14, 2006. Even if the two highest decline rates are excluded the mean decline on Nov. 14, 2006 from an assumed "initial" pressure of 2808 kPa is 5.8%. The declines have increased by 12.5% during this 2.5 month period alone. That is, the rates of decline are increasing by 5% per month.[13] The remainder of the Husky piezometer data (6 piezometers) are exhibiting anomalous behaviour. They are being more strongly affected by operations not related to the gas cap depletion, e.g. possibly due to nearby water disposal or response to gas cap operations.

Husky's piezometer data proves that rapid pressure decline is occurring throughout the bitumen zone due to adjacent gas production. It appears that the overall pressure decline levels and the pressure trends in the bitumen zone are not being disputed by EnCana as its claims to match the Husky piezometer data to precondition its simulation runs for the gas cap depletion sensitivity study.[14]

The pressure communication from the adjacent gas cap to the bitumen zone is unimpeded because there are no continuous vertical or horizontal permeability barriers as explained in the geology section. Husky's geological mapping indicates that the top water zone is areally more extensive than both the overlying gas zone in the east and south and the underlying shale zone in the east.[15] The pressure is communicated from the adjacent gas production to the bitumen through two means:

(i) pressure transients travels from the gas zone to the top water zone and from there to the bitumen zone laterally and vertically, and

(ii) where there is no top water zone, pressure is transmitted directly from the gas cap to the bitumen vertically and laterally.

Husky's reservoir simulation results demonstrate that the depletion of the offset gas cap reduces the pressure in the reservoir throughout the width of the simulation model (several hundred meters). **Figures 4.1 and 4.2** show that the pressure falls throughout the reservoir. In support of these simulation results, field data show that this distance is greater than 3 km. This is due to water mobility in the reservoir at original conditions, as has been established from relative permeability measurements.[16] Mobility of water at initial conditions must be included in reservoir simulation models of the Caribou Area.

[13] Husky's response to Board information request 2006-11-10.
[14] January 8th, KADE Simulation,
[15] Husky's response to EUB information request 2006-10-26
[16] Husky's response to EnCana information request 2006-11-10

As the pressure falls in the gas pool, the gas-water contact rises and adds to the volume and areal extent of the top water. **Figure 4.2** shows that after pressure depletion starts, the water saturation in the gas pool rises. Physically this is because of mobile water in the reservoir.

The piezometer pressure decline rate data is reasonably matched in Husky's reservoir simulation models.[17] For evolution of solution gas into bubbles in the pore space, the pressure decline rate is a key factor that controls the rate of solution gas bubble formation which ultimately impacts the critical gas saturation at which the gas phase becomes mobile. The absolute value of the pressure controls the amount of solution gas dissolved in the oil phase. No unusual flow barriers or adjustments to the net-to-gross ratio or modifications to the oil phase viscosity were done to achieve the history match. Rather, given that the model was a generic unit model of the field, the initial gas in place per unit model size was altered (i.e. total gas in the model was altered) until the pressure decline rate was matched. This is a simple and non-radical method to match the gas pool performance that does not alter the underlying geological model obtained from core and log data. It must be borne in mind that the metric used to obtain the gas pool pressure match conducted by Husky was the absolute deviation between the simulation-calculated and field-derived pressure decline rates. Consequently, Husky maintains that its model results are reliable because of the quality of the history match in its model.

5. Impact of Pressure Depletion on Bitumen Recovery

EnCana's ongoing production of gas from the gas cap continuously drops the pressure in the gas cap. This pressure drop propagates laterally throughout the gas cap and the subjacent bottom water zone, which underlies gas pools. This decline of the pressure is then transmitted down to the adjacent bitumen reservoir, as proven by Husky's piezometer data.

The decline of the pressure within the bitumen zone causes gas exsolution from the bitumen. The problem is that this loss of gas results in an increase in bitumen viscosity, and in a loss of solution gas drive. The increase in viscosity impedes any bitumen recovery process, and the loss of solution gas removes an important drive mechanism for CSS and HSAGD. As such, the declining pressure in the bitumen will adversely affect the subsequent HSAGD or CSS processes.

The pressure drop in the bitumen referred to above, is directly due to the production of gas from the gas caps. Shutting in the gas production will stop the pressure decline in the gas cap, which will stop the pressure drop in the bitumen reservoir. This will prevent further gas exsolution and its associated negative effects on the thermal recovery processes being proposed.

5.1 EnCana has failed to incorporate realistic geology into their reservoir model.

EnCana has failed to incorporate a realistic geological model of the Caribou Area into their numerical reservoir simulation model.

---

[17] Husky's response to EnCana information request 2007-01-19.

(a) Artificial transmissibility barrier between the water and the bitumen

In its reservoir simulation, EnCana arbitrarily and severely reduces the vertical transmissibility between the water and the bitumen zone below the gas cap by a factor of about 1,000,000.[18] The result is artificially create a barrier to vertical flow that extends for almost for the entire areal extent of the gas cap (Figure 5.1).

Husky does not incorporate any impermeable transmissibility barriers within its reservoir model. Based on core data, geophysical log data, and Husky's understanding of the depositional environments, there is absolutely no justification for introducing this barrier to vertical flow. In fact, our core analysis data and core work suggests that this shale should have permeability in the 30 to 500 mD range. Husky assigned this sandy shale layer a permeability of 50 mD and a porosity of 10%, based on the core analysis.[19] In addition to there being no laterally continuous barriers, the shale itself is permeable.

EnCana's arbitrary and unsupported transmissibility reduction essentially insulates the gas cap from the underlying bitumen, thereby severely limiting the pressure transmission that Husky has demonstrated to be occurring. The result of EnCana's creating an artificial barrier is that pressure drops in the gas cap do not appear to affect the pressures in the bitumen to the full extent. This results in EnCana's model predicting higher bitumen pressures and less gas exsolution. This understates the effect of gas cap depletion on bitumen recovery according to EnCana's model.

It is fundamentally incorrect for EnCana to introduce a "phantom" barrier to vertical flow in the Caribou Area.

(b) EnCana uses an unrealistically low net to gross ratio of 10% under the gas cap

By using a low net to gross ratio of 10% under the gas cap[20], EnCana has not only reduced the volume of bitumen in these layers, but has also reduced the horizontal transmissibility by 90%. (Figure 5.2) This, together with the vertical transmissibility barrier described above (Figure 5.1), nearly seals off the gas cap from the bitumen zone below. This reduces the effect of gas cap depletion on the pressures within the bitumen, thereby reducing the effect of continued gas production on the bitumen reserves. The use of a low net to gross ratio of 10% is unjustifiable.

Husky has used porosities, saturation and thicknesses populated from the geostatistical model based on actual well data. Husky's incorporation of actual data realistically demonstrates the existence of pressure transmissibility between the gas cap and the bitumen.

(c) The east shale (C-D Mud) was assigned an unrealistically low permeability that was not supported by laboratory data.

---

[18] EnCana Simulation models on CDs, EnCana response to January 12, 2007 Husky information requests.
[19] Husky's response to Board information request 2007-01-08
[20] EnCana Simulation models on CDs, EnCana response to January 12, 2007 Husky information requests.

An examination of EnCana's reservoir simulation input files[21] reveals that the East shale (C-D Mud) was assigned an unrealistically low permeability that was not supported by laboratory data. In fact, laboratory data confirms that it should have been in the 30 to 500 mD range[22] instead of the 0.001 mD used in EnCana's simulation. By incorrectly postulating the existence of a low permeability layer, EnCana effectively creates a barrier between the gas cap and the lower bitumen zone. This in essence separates the reservoir into two units, which precipitates the conclusions of EnCana's simulation study. Such a low permeability effectively forms a barrier between the gas cap and the lower bitumen zone.

Husky has used conservative shale permeability for the East shale (C-D mudstone) in its simulations, based on the laboratory data given below (provided in IR response 4, October 17, 2006).

Table 1: Laboratory and Simulation Shale Permeabilities and Porosities

	496.3m - 496.4m	499.9m - 500m	Reservoir Simulation
Maximum Permeability, k_{max}	526 mD	29 mD	50 mD
Porosity, ϕ	34.0%	29.8%	10%

By assuming a shale permeability that is 30,000 to 300,000 times smaller than that supported by laboratory data, EnCana has again artificially insulated the underlying bitumen reservoir from pressure changes caused by gas cap depletion. This would severely inhibit the pressure transmission across this shale and into the underlying formations, including the bitumen reservoir. As such, in EnCana's simulation work, this would minimize gas exsolution within the time frame of the simulation, thereby minimizing the effects of gas cap production on the bitumen reserve.

(d) Permeability data is not representative of the Clearwater Formation

EnCana's permeability plots exclude all Husky 2005 data and underestimate the average permeability based on commercial data base values, that replaced horizontal permeability with vertical permeability, and excluded horizontal permeability entirely.

Husky's reservoir simulation model used permeability data that are representative of the Clearwater reservoir in the Caribou Area, as determined using Husky's core analysis.[23] Husky contends that a correct numerical simulation should be based on the best data available.

EnCana claims that its model can still "match" the piezometer data, despite the fact that EnCana uses the wrong permeabilities. One cannot match the pressure data with a flawed model.

---

[21] January 8th KADE Simulation

[22] Husky Oil Operations Limited, *Impact of Gas Cap Depletion on Bitumen Recovery in Cold Lake Clearwater Formation*, January 8, 2007 ("January 8th Husky Simulation")

[23] Husky's response to EnCana January 12, 2007 information requests

(e) EnCana does not include reservoir heterogeneity

EnCana does not consider reservoir heterogeneity, other than to construct a deterministic model of the reservoir. This is an overly simplistic approach to the reservoir's heterogeneity.

The heterogeneity of the reservoir is a key factor that must be included in models (Deutsch, 2002). To accomplish this, Husky used geostatistical methods to include an unbiased representation of heterogeneity in the reservoir simulation model, using data from four wells located in the central portion of the incised valley. These four wells provide a reasonable representation of the area that is a candidate for thermal recovery, and which is likely to be impacted negatively by depletion of the adjacent gas zone.

Deterministic methods can be used to generate heterogeneity. However, the heterogeneity has to be introduced subjectively with such methods and the result will not be unbiased. The general procedure used by Husky is described in the IR dated January 8, 2007. Even though a single realization was used to build the reservoir model, all realizations generated by geostatistics are considered equiprobable and will demonstrate the same effect.. Since the size of the model is significantly larger than the scale of the heterogeneities, it is reasonable to use a single realization. In this context, the model used in this study is representative of uncertainties associated with characterizing the Clearwater Formation.

Husky's geostatistical analysis demonstrates that a reservoir simulation model has been constructed that honours the heterogeneities observed at the four wells, e.g.calcite layers and mud rich bitumen zones are represented in Husky's model. This is superior to a layer cake model where heterogeneity is not included and no well data is honoured as in the EnCana simulation model.

As can be seen from the discussion above, the physics of the process and the geology of the reservoir are represented in Husky's simulation model. Consequently, the results of the reservoir simulation model are a fair representation of the analysis of the risk to the bitumen resource due to gas cap depletion.

(f) Summary

EnCana's reservoir simulation model requires the creation of various barriers or restrictions to flow between the gas cap and the underlying bitumen. These features are geologically unjustifiable. Gas cap volumes have to be arbitrarily increased in order to match the observed pressure declines.

Husky's reservoir simulation models are consistent with the geology, rock-fluid, and fluid properties of the Clearwater reservoir. The models have no unusual features added to achieve the history match and capture all of the major physics of the thermal processes under evaluation. The models are detailed, with sufficient grid resolution. Husky's models demonstrate that gas cap depletion can impair production of adjacent bitumen resources and that these resources should be conserved.

5.2 EnCana's reservoir simulations are fundamentally flawed.